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Environment
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Management

Wakaw Lake Fisheries Assessment 1999

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1. INTRODUCTION

Wakaw Lake is located 64 km south of Prince Albert, and approximately 100 km northeast of Saskatoon. Due to its central location, the lake is very popular for fishing, swimming, water-skiing and other water-based recreational activities. There are approximately 700 cabins situated along the shoreline, plus a regional park, several resorts, and numerous group camps. Good access to the lake is available both from Highway # 2 and Highway # 41 (Fig. 1).

The lake is fed by seepage and runoff (primarily snow melt and spring rains), and outflow is via the Carrot River into the Saskatchewan River in Manitoba. A proposal to install a control structure at the Carrot River outlet to maintain water levels has been a controversial issue for many decades. In 1987, plans were drawn up for the structure. However, due to conflicting opinions about desirable water levels, and potential for flooding of several subdivisions, the structure has not been constructed, to date.

Wakaw Lake is situated within the fertile agricultural belt of the aspen parkland. Clearing of vegetation to the waters's edge has occurred over much of the shoreline for agricultural and recreational developments. This activity has expedited nutrient loading into the lake. A number of residents around the lake have complained about sedimentation into the lake, and increased weed growth.

Due to the large amount of development around the lake, much of the natural shoreline has been altered and disturbed. Since the mid 1980s, Saskatchewan Environment and Resource Management has had a permitting system in place that requires anyone doing work near water obtain a Shoreland Alteration Permit. Since much of the riparian area has been disturbed, it is important to protect remaining areas that provide important aquatic habitat. In 1993, SERM - Fisheries Branch conducted a fish habitat assessment to identify and map marginal, important and critical areas of the lake. Results are attached as Appendix 1.

Since 1969, Wakaw Lake fish populations have been surveyed routinely every four to five years by Saskatchewan Environment and Resource Management. An earlier study, carried out in 1955 provides some baseline information on the morphometry and limnological characteristics of Wakaw Lake. Between 1934 and 1956, a total of 5.5 million walleye fry were stocked into Wakaw Lake. Studies since that time have indicated that natural reproduction has been capable of maintaining walleye populations, and stocking has been discontinued. Utilization of the gamefish resource is solely by the sport fishery, although several licenses have been issued for commercial bait fishing.

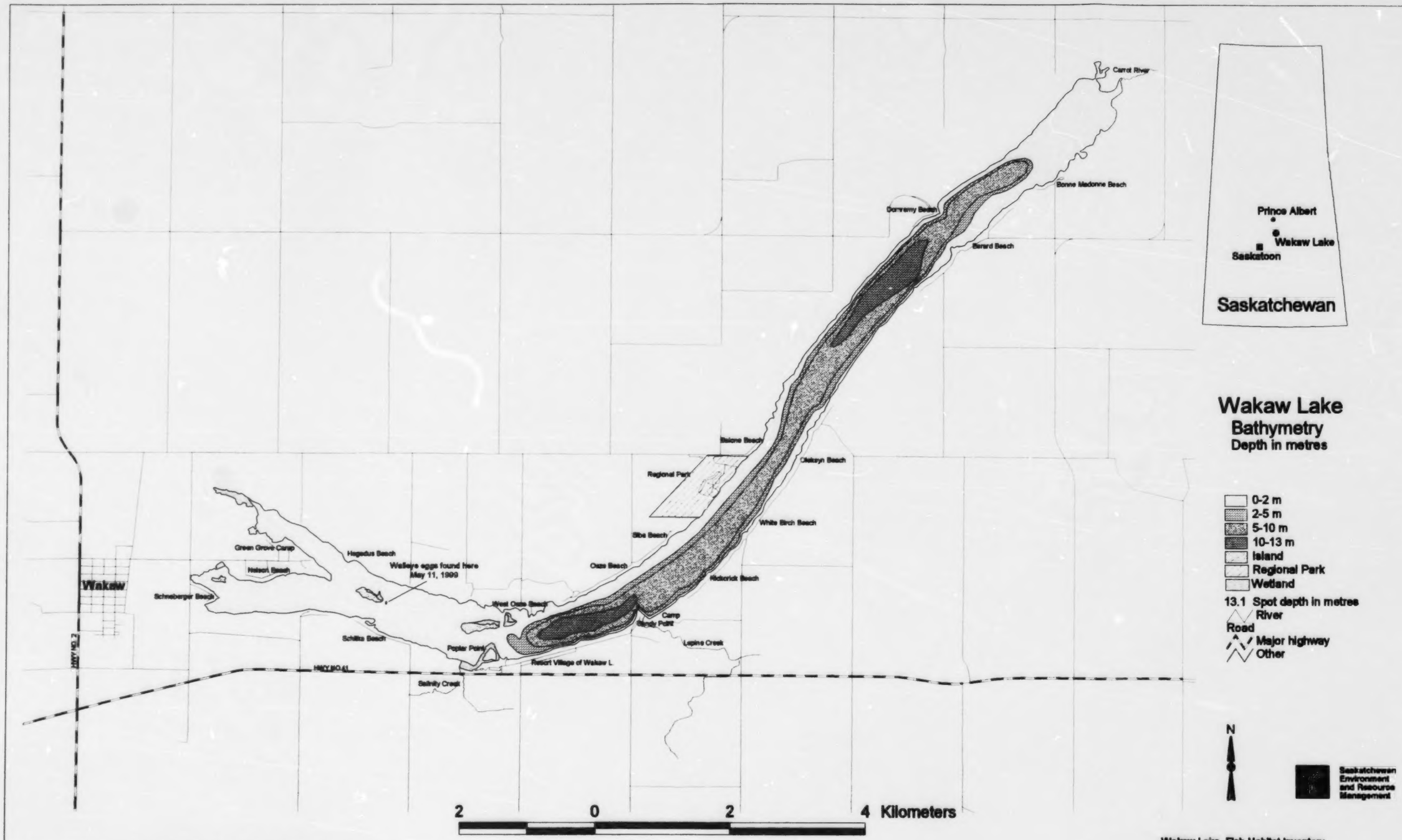


Fig. 1. Wakaw Lake and surrounding area.

Wakaw Lake Fish Habitat Inventory
Saskatchewan Fisheries Lab. July 1998

Fish kills have been reported from Wakaw Lake since 1979. In recent years, localized kills have occurred in sheltered bays, and have mostly affected small perch and minnows. These local die-offs are likely a result of anoxia following an algal bloom. During the summer of 1993, two fish kills were reported: along Bonne Madonne Beach on the northeast end of the lake, and in the northwest bay. In 1994 and again in 1997, localized fish kills were also reported. The most recent fish kill, reported in July, 1999, affected approximately 100 small perch near West Osze Beach.

Results of the sport fish surveys since 1988 have shown a declining trend in numbers of walleye. Concerns about the declining fish resources, the water quality and the possible impacts of future developments around the lake prompted Saskatchewan Environment and Resource Management to carry out the present investigation.

Objectives of the present survey included:

- determination of the present status of the fishery resource, particularly in relation to past surveys;
- determination of present harvest rates of the gamefish populations and comparison to estimates of potential yield;
- recommendation of management changes needed to ensure the resources are maintained in a healthy state.

2. METHODS

2.1 PHYSICAL AND CHEMICAL PARAMETERS

Morphometric parameters of Wakaw Lake were updated in 1998, using information collected during the fish habitat assessment. Features were extracted from a 1:50 000 topographic source map. New soundings were taken in 1993 for the littoral (<2 m) zone.

In addition to updated lake morphometry, the 1993 fish habitat assessment collected information on backshore development (slope, land use, vegetation) and foreshore features (substrate type and vegetation).

Limnological measurements were carried out on several dates during the 1999 survey in the deeper basin of the lake. Parameters measured consisted of a temperature-dissolved oxygen profile, pH, conductivity and water clarity. Locations were marked using a Global Positioning System (GPS). A YSI Model 57 dissolved oxygen meter was used to determine the temperature-oxygen profile throughout the water column. An Accumet AP50 portable Meter was used to determine pH and conductivity. Water clarity was measured by the secchi depth method.

On September 1, 1999, water samples were collected at three sites on Wakaw Lake for further analyses. Results of this sampling are included as Appendix 2. Results obtained were compared to an earlier study done by SERM in 1979-80, which at that time concluded that the lake water quality met the provincial criteria for contact recreation and the protection of aquatic life.

2.2 ASSESSMENT OF THE FISH RESOURCES

Sampling for walleye eggs was carried out on May 11 and on May 21, 1999. An air-lift egg sampler (a generator-run vacuum hose covered with a mesh bag) was used in the shallow, rocky shoal areas. These areas had been previously identified as important-critical walleye spawning habitat in the 1993 fish habitat assessment. The air-lift sampler was used in areas from 30 cm to 100 cm deep, and a dip net was used in areas shallower than 30 cm.

Young-of-the-year gamefish, and forage fish were collected using seine nets and minnow traps. Seine nets were pulled along the sandy shores in depths up to 1.5 m. On several occasions, a boat was used to pull one end of the seine net with the other end pulled along the shoreline. Minnow traps were set in sheltered, near shore areas and left overnight. No bait was used in these traps.

Large fish species were sampled using standard gang gillnets, and an electro-fishing boat. Gillnets consisted of 60 m quarter standard gangs (10 m each of 3.8, 5.1, 7.6, 10.2, 12.7 and 14.0 cm stretched mesh), and 120 m long half standard gangs (20 m of each mesh size). The nets were left overnight, and pulled the following day. Locations of each net set were identified by GPS, and sites duplicated previous net sets in 1993 and 1997. Fish were analyzed by fork length, weight, sex and state of maturity. Food habits were investigated on a representative sample of fish. Bony structures were taken from the majority of fish for ageing: otoliths were taken from walleye and perch, and cleithra were taken from pike. Gillnets were set for several nights in June, July and September to obtain a more accurate picture of fish distribution and abundance throughout the open-water season.

In September, 1999, the electro-fishing boat (Jolter 1) was used in the shallow areas along much of the shoreline of Wakaw Lake. Electro-fishing provides an alternate method for sampling fish that are not susceptible to gillnetting, such as pike, burbot, and sculpins. It is also a non-lethal method for sampling fish. The fish are momentarily stunned by an electrical current, and at this time they can be dipnetted, measured and released, or put into a distribution tank for further examination. The electro-fishing boat was used at night, as the fish come into the shallow waters to feed and are more susceptible to the current. The underwater lights of the boat provide excellent visibility during the dark hours.

The Coffelt VVP 15 electro-fisher, powered by a Honda EB 5000 generator, has two voltage ranges (300-600 volts), both AC and DC currents, and the ability to pulse both currents. Typically a pulse DC current is used. The voltage range used is dependent on the conductivity of the water. The aluminum hull of the Jolter serves as the cathode, and two booms are typically used as the anode. With the high conductivity of Wakaw Lake (3500 µS/cm) some modification was made to the anode: a single boom consisting of a copper pole was dropped into the water just 6-8 inches. Settings of the electro-fisher used on Wakaw Lake are given:

Output mode	Pulsed DC
Volts	50-75
Current	10-12 amps
Pulse width	40% at 120 freq
Running time	30 min stretches

Further specifications of the electro-fishing boat are given in Blixrud (1996).

2.3 ANGLER SURVEY

A creel census was carried out from opening day of fishing season in May up to and including the September long weekend to determine fishing pressure and harvests of gamefish on Wakaw Lake. The survey was conducted by boat, and in general the interviewer made two or three complete circuits of the lake during each shift. Anglers were interviewed while actively fishing. The fishing day was divided into three shifts:

8:00 a.m. - 12:00p.m.
12:00 p.m. - 4:00 p.m.
4:00 p.m. - 8:00 p.m.

A schedule was drawn up prior to opening day, designating the shift, and date on which the census would occur. Days and times of coverage were picked using a computer to generate random days and shift times. Two weekend days, and two weekdays were sampled per month from May to August. Only one weekday and one weekend day was covered in September. A sample interview form is included as Appendix 3. Days of coverage, and the hours covered, are given in Appendix 4. Because Wakaw Lake is so long and narrow, travel by boat is fairly quick, and it was felt that during a shift, all anglers were either contacted, or observed and noted. Therefore, no correction for missed coverage was made. Anglers were interviewed only once during the day regardless of the number of times they were observed. Information collected included the entire fishing day, in terms of hours fished and numbers of fish caught.

Fishing effort was estimated by using the total boat count methodology. Total counts (including both boat and shore parties) were made in the morning, afternoon and evening. These counts were added together to get a daily count, and then averaged to obtain number of parties fishing per day over the season. Weekdays and weekends (including statutory holidays) were treated separately. Angler days were determined from the number of parties multiplied by the average number of anglers per party and the number of days during the survey period that fell into either weekdays or weekends. Angler hours were estimated from the number of angler days multiplied by the average number of hours fished per trip, where the trip consists of the total effort expended in one day.

The total number of fish caught and kept was calculated by angler-hours and an hourly success rate. Harvest was estimated using the average weight of fish landed by anglers for pike and walleye: fork lengths of these species were measured during angler interviews, and average weights determined using the length-weight equation derived from fish captured in the standard gang gillnets from Wakaw Lake in 1999. Harvest of perch was estimated from the average weight of perch netted in the 1999 gillnets.

In addition to the angler survey, the gut cans at Wakaw Lake Regional Park were examined on a daily basis by Regional Park staff to estimate the type and amount of fish waste.

3. RESULTS

3.1 MORPHOMETRY

Wakaw Lake is a long, narrow lake lying predominantly in an east-west direction. The lake is approximately 18 km long, and 0.8 km wide (Mendis 1956). The water area, newly calculated by Liaw in 1993 (see Appendix 1), is 1166 ha. Maximum depth of the lake is 13.1 m, and mean depth is 3.5 m. Although the lake is relatively deep in the central basin, almost 60% of the waterbody is less than 2 m deep (Fig. 1). More detailed morphometric parameters are found in Appendix 1.

3.2 WATER QUALITY

Basic water quality parameters were measured on each visit to Wakaw Lake in 1999. Results are given in Appendix 5. Surface water temperatures varied over the summer months from a minimum of 7.8°C on May 11 to a high of 20.0°C on July 19. Wakaw Lake is well-mixed, and little fluctuation in temperature occurs within the water column. Dissolved oxygen ranged from 11.9 mg/L at 1.0 m depth on May 21, to a low of 3.5 mg/L at 10.0 m on September 1. The water column was fully saturated with oxygen to about the 10 m depth in May and June. In July, and September, a depressed saturation was noted.

The pH of the surface water varied from 8.26 on September 1 to 8.70 on June 14. Conductivity measurements ranged from 2740 µS/cm on July 19 to 3660 µS/cm on September 21. Water clarity, as measured with a secchi disk, ranged from 2.0 m in June to 2.5 m in September.

Detailed water analyses from September 1 are given in Appendix 2. Results indicate that all parameters corresponding to specific Saskatchewan Water Quality Objectives (1995) were met for the protection of aquatic life and contact recreation. Values are also compared to results obtained in an earlier 1979-80 comprehensive study on Wakaw Lake water quality. The majority of parameters (pH, phosphorus, total nitrogen and chloropyll *a*) measured showed little variation from earlier measurements. Conductivity showed a slight increase in 1999, and total coliform bacteria counts were higher. The September, 1999 sampling indicated that oxygen saturation was less than in earlier studies. Although sampling in May and June in 1999 revealed full saturation of the water, by September, organic processes were occurring that could lead to oxygen depletion. Even in deep areas of the lake, a strong smell of hydrogen sulphide was noticeable on the September sampling date.

3.3 FISH STATUS

3.3.1 Species Composition

Numbers and species of fish captured in Wakaw Lake in 1999 by seine haul, minnow trap, standard gang gillnet and electro-fishing are given in Appendices 6-9. Sampling revealed that a variety of fish species is present in Wakaw Lake, corresponding to findings in 1956:

Species	Common Name	Collected in 1956	Collected in 1999
Stizostedion vitreum	Walleye	X	X
Esox lucius	Northern pike	X	X
Perca flavescens	Yellow perch	X	X
Catostomus commersonii	White sucker	X	X
Culaea inconstans	Brook stickleback	X	X
Etheostoma exile	Iowa darter	X	X
*Etheostoma nigrum**	Johnny darter	X	?
Notropis hudsonius	Spottail shiner	X	X

*Darters were not all keyed out to species. Those exhibiting brilliant spawning colours were considered to be Iowa darters.

Seine nets were used along the shallow areas to collect forage fish and young-of-the-year game fish. Seining in Wakaw Lake is very difficult due to the large amount of ooze that comprises the bottom sediments. Using the boat to pull one end of the net increased the effectiveness of the sampling. This method captured largely small perch and spottail shiners.

Minnow traps were not efficient in capturing fish. Only a few perch, spottail shiners, darters and sticklebacks were caught.

Numbers and species of fish captured in the 1999 standard gang gillnets are given in Appendix 8. Catch results from the standard gang gillnets from 1969 to 1999 are given below. Since length of nets used in 1956 was not known, data from that year are not included in the comparison.

Catch Comparison
Number of fish per 100 m of net

	1969	1974	1978	1983	1988	1991	1993	1997	1999
Walleye	40	18	50	42	52	29	19	12.4	27.4
Pike	3	18	2	10	7	8	5	5.0	11.9
Perch	6	0.5	7	29	28	19	12	7.6	8.8
Sucker	24	15	26	42	6	8	11	13.3	29.6
Total	73	51	85	123	93	64	47	38.3	77.7

White sucker was the most abundant species captured in the 1999 gill nets, comprising almost 40% of the catch by number. Walleye was second in abundance, comprising about 35% of the fish captured. Results are depicted graphically in Fig. 2.

3.3.2 Analyses

	No.	Fork length, cm	Weight, g	Age
Walleye	12	24.5 - 27.5	140 - 230	2
	48	20.5 - 35.0	180 - 450	3
	7	27.0 - 43.5	200 - 800	4
	45	31.5 - 49.0	650 - 1340	5
	58	38.6 - 52.4	700 - 2000	6
	3	49.0 - 53.0	1050 - 1700	7
	4	47.5 - 52.5	1200 - 1450	8

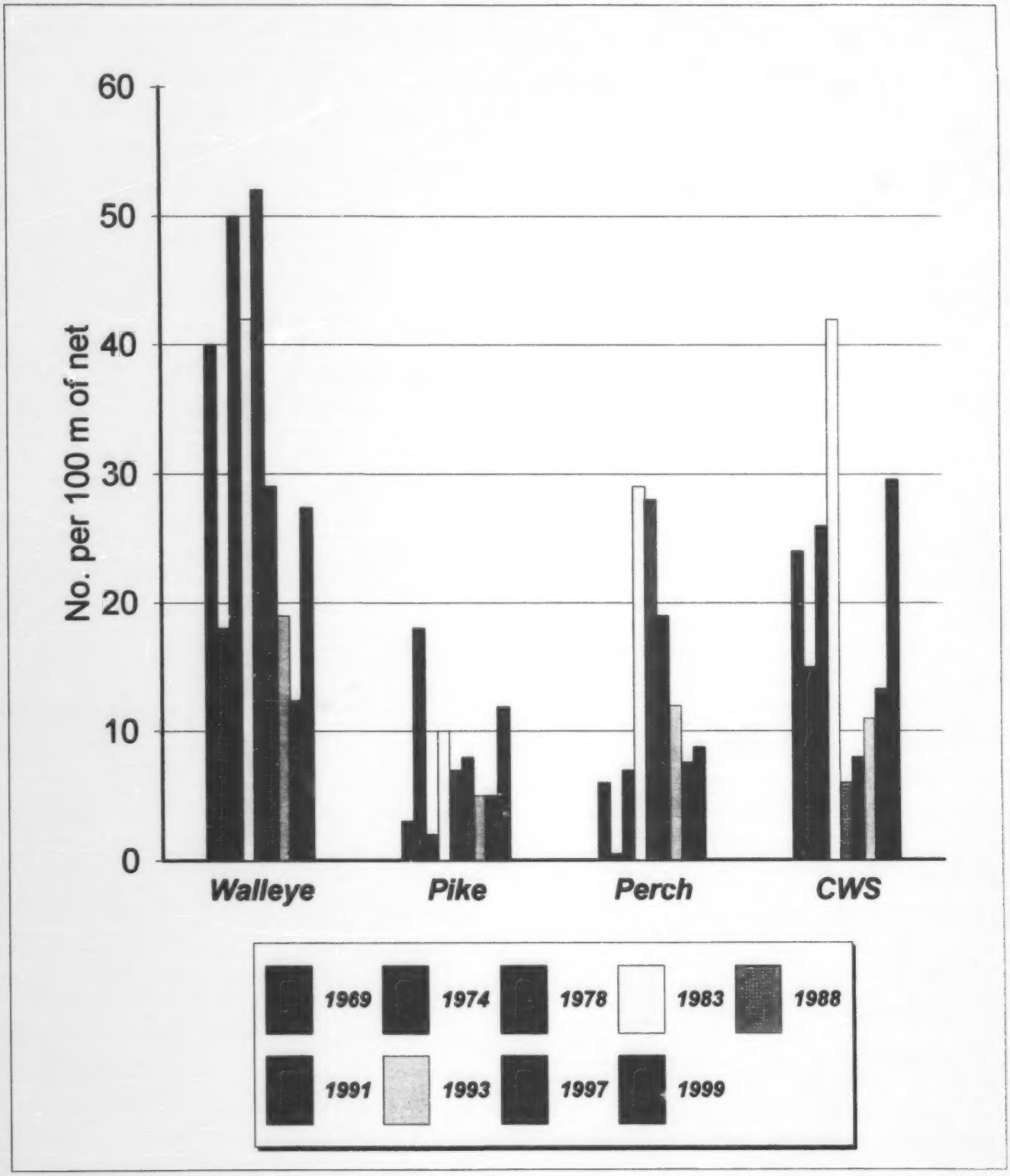


Fig. 2. Fish species catch composition in Wakaw Lake. CWS=white sucker

	6	46.4 - 55.0	900 - 1900	9
	25	43.6 - 57.6	720 - 2000	10
	20	46.6 - 60.4	900 - 2300	11
	11	47.5 - 60.6	1100 - 2750	12
	9	47.2 - 56.5	1000 - 1900	13
	6	49.0 - 56.0	1000 - 1650	14
	1	44.5	1000	15
	1	54.0	1200	18
	1	59.5	2010	19

	No.	Fork length, cm	Weight, g	Age
Pike	3	23.0 - 25.3	90 - 120	0
	16	24.0 - 38.0	90 - 380	1
	24	25.0 - 52.5	100 - 1000	2
	56	42.5 - 63.5	600 - 1950	3
	24	45.0 - 64.0	600 - 1950	4
	16	53.0 - 68.0	1000 - 2400	5
	4	58.0 - 69.5	1650 - 2400	6
	2	72.0 - 80.5	3000 - 4000	8
	1	73.0	2500	9
	1	86.5	4200	10
Perch	40	<18.0	<50	
	3	18.0 - 19.5	80 - 90	5,8
	4	20.0 - 21.6	120 - 140	8,9

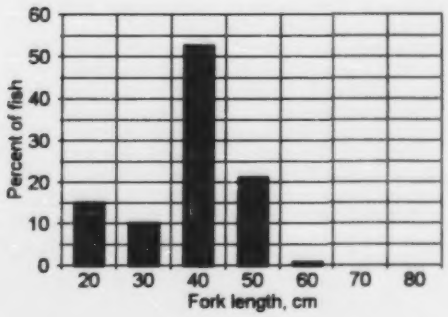
3.3.2.1 Walleye

Sampling for walleye eggs was carried out in areas previously identified as good potential walleye spawning habitats on May 11 and May 21, 1999. Water temperatures at the time of sampling varied from 7.8° C to 10.6° C. Areas sampled included the rocky shoals of the islands at the west end of the lake, the rocky shoreline south of the Regional Park, and along the wind swept beach beside Sandy Point. One live walleye egg was recovered from the smallest island (now known as Walleye Island: see Fig. 1): no further eggs were obtained. Many of the sites identified as critical for walleye spawning areas were covered with silt due to lack of wind and wave action.

Three young-of-the-year walleye were captured by seining at Nickorick Beach on July 19, 1999. The other walleye captured in the seine nets were larger, approximately one kilogram in weight. Lengths and weights of the young-of-the-year fish were taken:

Total length, cm	Weight, g	Stomach contents
5.0	0.75	Empty
5.8	1.05	Empty
6.0	1.12	Empty

A total of 296 walleye were captured in the standard gang gillnets in 1999 (Appendix 8). Based on numbers of fish captured per 100 metres of gillnet, a good population of walleye occurs in Wakaw Lake. Populations have increased in abundance, and are similar to results obtained in 1991. Numbers are still less than what was encountered between 1978 and 1988. Walleye captured in the gillnets ranged in fork length from 24.5 cm to 59.5 cm, with an average of 43.6 cm. The majority of walleye fell within the 40 - 60 cm length intervals. Approximately 9% of walleye were longer than 55 cm in fork length.



Weights of walleye varied from 140 g to 2750 g. A comparison of average fork lengths and weights of walleye captured in 1999 with walleye caught in earlier surveys is given below:

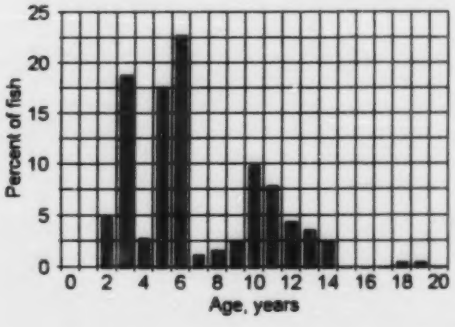
Year	Length, cm*	Weight, g
1988	39.1	753
1991	44.1	911
1993	41.3	762
1997	44.2	1010
1999	43.6	975

*Fork length

The length-weight relationship for walleye was determined for the fish captured in the 1999 gillnets:

$$W = 0.0101\ L^{3.0037}$$

Ageing analyses, as determined from otoliths, revealed that walleye varied in age from 2 to 19 years, with the majority falling between 3 to 6 years.



A large variety of length and age classes of walleye are present in Wakaw Lake.

A total of 245 walleye captured were examined for food content. Frequency of occurrence of food items is:

Organism	% Occurrence
Fish remains-unidentified	23.8
Perch	5.7
Spottail shiner	1.2
Invertebrates	0.4
Insects	0.2
Unidentified remains	0.8
Empty	67.8

Most of the walleye examined had empty stomachs. Of those containing food, fish remains (primarily perch) was the most common item encountered.

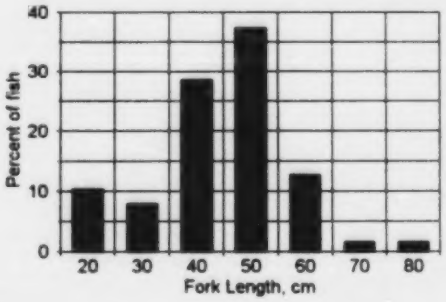
State of maturity of fish was noted at the time of the survey. At age 3, less than 5% of the walleye were mature. At age 4, almost 60% of the fish were mature, and by age 5, over 80% were mature. Since most immature fish were not classed as either male or female, differences in rate of maturity between the sexes could not be determined.

3.3.2.2 Pike

Although seining was carried out in many of the near-shore weedy areas, no juvenile pike were captured by this method. However, young-of-the-year pike were captured in the gillnets in September, and over 80 were sampled by the electro-fishing boat. Analyses of several of these fish revealed a range in fork length from 23-25 cm, and weights of 90 to 120 g.

A total of 128 pike were captured in the standard gang gillnets in 1999 (Appendix 8). Based on numbers of fish captured per 100 metres of net, a moderate population of pike is present in Wakaw Lake. Numbers of pike captured by gillnet has increased in abundance since 1978. Only in the 1974 survey were more pike caught (Fig 2).

Pike ranged in fork length from 23.0 cm to 86.5 cm, with an average length of 49.2 cm. The majority of pike fell within the 40 to 60 cm length interval.



Weights varied from 90 g to 4200 g (almost 10 lbs). A comparison of average fork lengths and weights of pike captured in 1999 with those caught in nets in earlier surveys is given:

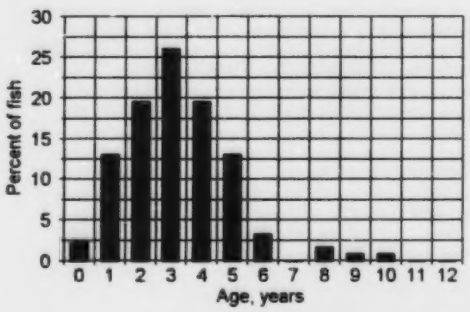
Year	Length, cm*	Weight, g
1988	47.2	870
1991	59.9	1720
1993	54.3	1410
1997	52.4	1160
1999	49.2	1025

*Fork length

The length weight relationship was calculated for pike captured in the 1999 gillnets:

$W = 0.0059\ L^{3.0198}$

Ages of pike, as determined from cleithra, ranged from 0 to 10 years, with the majority of fish varying from two to four years. The graph shows a good variety in age classes of pike in Wakaw Lake.



A total of 114 pike were examined for food habits. Frequency of occurrence of food items is:

Organism	% Occurrence
Fish remains-unidentified	7.0
Perch	7.0
Shiner	1.8
Empty	84.2

The majority of pike examined had empty stomachs. Of those containing food, fish remains (primarily perch and shiner) were the only items encountered.

Several of the female pike examined in mid-summer contained fully developed eggs. One specimen was sent to the pathology department at the Canadian Co-operative Health Centre for analysis. No abnormalities were noted other that the fish had not spawned.

State of maturity of fish was noted. By age 2, 70% pike were mature, and by age 3, 90% were mature. Since immature fish were not classed as either male or female, differences in maturity rates between the sexes was not determined.

3.3.2.3 Perch

Perch was the most abundant species of fish collected by seining in Wakaw Lake in 1999 (Appendix 6). Several were also caught in the minnow traps. Ninety-five perch were captured in the standard gang gillnets (Appendix 8). The majority were less than 18 cm in fork length, averaging 15.7 cm in length and approximately 50 g. Several of the larger perch were aged, using otoliths, at 5, 8 and 9 years. Although the perch are small in size, they are a good sport fish, especially for children.

Seven of the larger perch were examined for food habits. Of these, three contained fish remains: the remaining four had empty stomachs.

3.3.2.4 Other Species

White sucker constitutes the only other large fish species present in Wakaw Lake. In 1999, this species was the predominant species captured by the standard gang gillnets. This species has increased in abundance in the last decade. Although not utilized to any extent, this species provides an important food item for the other gamefish.

Little analyses was carried out on this species. Length and weight measurements were taken from a sub-sample of 36 white suckers. Fork lengths varied from 17.5 cm to 53.0 cm, and weights from 75 g to 2200 g. No ageing analyses was done, and no suckers were examined for food habits.

3.4 THE SPORT FISHERY

3.4.1 Angling Pressure

An estimated 10 560 angler-days were spent fishing on Wakaw Lake between May 8 and September 5, 1999 (Appendix 10). Each fishing trip lasted approximately 2.4 hours. From these values, an estimated 25 350 angler-hours were spent on Wakaw Lake. Tables 1 and 2 give the angling statistics for Wakaw Lake and the determination of fish harvest. Fishing pressure is calculated to be equivalent to 9.1 angler-days/ha.

The majority of anglers (61.3%) fishing at Wakaw Lake during the summer of 1999 were aged 16-64 yr (Table 3). Anglers under 16 yrs of age comprised 35.8% of those fishing on Wakaw Lake: many children were interviewed as they fished from the docks. Seniors made up a relatively small percentage (2.9%) of the anglers interviewed.

3.4.2 Angler Origin

The majority of anglers interviewed at Wakaw Lake in 1999 were from Saskatchewan: the remainder came from other western provinces, USA and Europe (Table 4). Of Saskatchewan residents who were interviewed, most lived in Saskatoon (55%). People from nearby Saskatchewan communities comprised 31.5% of those anglers interviewed.

Table 1. Determination of harvest of gamefish on Wakaw Lake, May 8 - September 5, 1999.

	No. Fish/hr			No. Fish				
	Caught	Kept	Total ang-hr	Caught	Kept	Avg. Wt fish, kg*	Total wt fish, kg	Harvest kg/ha
Pike	0.23	0.11	25 350	5830	2790	0.94	2620	2.3
Walleye	0.05	0.03	25 350	1270	760	0.74	560	0.5
Perch	0.64	0.09	25 350	16 220	2280	0.05	110	0.1
Total	0.91	0.22		23 320	5830		3290	2.9

* Average weights for pike and walleye were determined from fish landed by anglers in 1999, using a length-weight equation derived from the gamefish captured in the 1999 standard gang gillnets. Average weight of perch was determined from fish captured in the 1999 standard gang gillnets.

Table 2. Angling statistics for Wakaw Lake, May 8 - September 5, 1999.

Area, ha	1 166
Angling effort:	
Angler-days	10 560
Angling effort, hr/day	2.4
Angler-hours	25 350
Angler-day/ha	9.1
Angler-hours/ha	21.7
Gamefish - caught:	
No./angler-day	2.2
No./angler-hr	0.9
No./ha	20.0
Gamefish - kept	
No./angler-day	0.5
No./angler-hr	0.2
No./ha	5.0
Gamefish - harvest:	
Kg/ha	2.9

Table 3. Age of anglers fishing Wakaw Lake from May 8-September 5, 1999.

Age Group, yr	Number	%
Under 16	152	35.8
16-64	260	61.3
Over 65	12	2.1
Total	424	100.0

Table 4. Origin of anglers fishing at Wakaw Lake, 1999.

Place of Origin	Number	%
Saskatoon	407	55.0
Wakaw	28	6.9
Humboldt	13	3.2
Prince Albert	10	2.5
Other Sask. centres	128	31.5
Total Saskatchewan	407	97.6
Alberta	4	1.0
Manitoba	1	0.2
United States	3	0.7
Other (Germany)	2	0.5
Total	417	100.0

Table 5. Numbers of anglers and where they stayed at Wakaw Lake, 1999.

Accommodation	Number	%
Cabin Owner	254	60.6
Campsite	104	24.8
Day Visit	61	14.6
Total	419	100.0

As indicated in Table 5, over 60% of the anglers interviewed were cabin owners at Wakaw Lake. The remainder were either camping (24.8%), or came to the lake for a day visit (14.6%).

3.4.3 Fishing Success

Anglers fishing Wakaw Lake in 1999 caught an average of 0.9 fish per angler-hour (Tables 1 and 2). This is somewhat less than the 1.2 fish per angler-hour captured by anglers in the 1980 angler survey (Merkowsky and Durbin 1984). Wakaw Lake anglers have intermediate success when compared to anglers in other central Saskatchewan water bodies:

Waterbody	Fish Caught/ angler-hr	Source
Wakaw Lake (1980)	1.2	Merkowsky & Durbin 1984
Jackfish Lake	1.2	Durbin 1980
Tobin Lake	0.9	Durbin 1981
Wakaw Lake (1999)	0.9	Present study
Blackstrap Lake	0.4	Fishing for Tomorrow 1995
North Sask. River	0.3	Merkowsky 1987

3.4.4 The Catch

An estimated 23 320 fish were captured by anglers fishing Wakaw Lake during the summer of 1999 (Table 1.) However, only 5830 fish, or 25%, were actually kept. This is due to the large numbers of small perch captured and released. Approximately 50% of the fish kept were pike; the remainder were walleye (13%) and perch (40%). Very few anglers even approached a daily limit. In terms of percent of walleye kept per angler, only 0.2% of anglers kept 4 fish, 0.5% kept 2 fish, 5.7% of anglers kept between 1-2 walleye, and the remaining anglers kept no walleye. For pike, 2.6% of the anglers kept between 1-2 pike, 2.6% of anglers kept 1 pike, 20.7% kept between 0-1 pike, and the remainder kept no pike.

An estimated 5830 pike were landed by anglers during the survey period. Fork length measurements of pike captured by anglers ranged from 30-74 cm, with an average length of 48.7 cm. Using the length weight equation generated for pike from the 1999 standard gang gillnet catch, average weight of pike captured by anglers was determined to be 940 g.

An estimated 1270 walleye were caught by anglers during the 1999 survey. Fork lengths of these fish ranged from 25-56 cm, with an average length of 39.7 cm. Using the length-weight equation for walleye captured by the 1999 gillnets, average weight of walleye taken by anglers was 740 g.

An estimated 16 220 perch were captured by Wakaw Lake anglers. Less than 15% of these fish were kept. Very few perch were measured: the majority of fish were less than 18 cm in size. To estimate average weight of perch taken by anglers, the average weight of fish caught in the standard gang was used.

A harvest of 3290 kg was estimated for the Wakaw Lake sport fishery from May 8 - September 5, 1999, based on the number of fish kept by anglers and the average weight (Table 1). This is equivalent to 2.9 kg/ha, which is substantially less than the 15.8 kg/ha determined for the sport fishery in 1980.

Results of the gut can counts made at Wakaw Lake Regional Park predict similar harvest levels (Appendix 11). Interviews with anglers throughout the summer indicated that only those people staying at the Regional Park utilized the filleting facilities located there. The estimated harvest of 1100 kg taken by anglers in the Regional Park comprises about 30% of the total predicted harvest.

3.4.5 Calculation of Fish Production

Estimation of the potential production of gamefish is given in Appendix 12 , based on the method derived by Ryder (1965). The 1980 figures were adjusted, based on the relative abundance of gamefish captured in the 1999 gillnet sets.

Using Ryder's morpho-edaphic index, a potential production of gamefish from Wakaw Lake is estimated to be 20.1 kg/ha/yr. As no commercial or domestic fisheries operate on Wakaw Lake, the fish are exploited only by anglers. The estimated harvest of 2.9 kg/ha taken by the sport fishery is far below the lake's potential production of gamefish.

4. DISCUSSION

The fish resources in Wakaw Lake were assessed during the summer of 1999, using a variety of methods including seining, gill-netting, and electro-fishing. An angler survey was carried out to determine the fishing pressure on the lake and to estimate the harvest of gamefish. Water quality parameters were also monitored throughout the season.

Water quality results indicate that the parameters measured fell within the guidelines of the Saskatchewan Water Quality Objectives (1995) for the protection of aquatic life and contact recreation. Oxygen depletion in the water column in late summer suggests that unexplained organic processes are occurring. Further investigation is required to determine the extent and to assess potential impacts.

Results of the fisheries assessment indicate that a good walleye population occurs in Wakaw Lake, similar to levels encountered during previous studies carried out in 1991. Numbers of walleye, although increased since the 1993 and 1997 surveys, remain below numbers encountered before 1993. The fishery is characterized by an abundance of age classes, suggesting a healthy, stable population. The population is maintained by natural reproduction, since stocking has not taken place since the mid 1950s. The capture of a live walleye egg, and several young-of-the-year fish verifies that this species is reproducing successfully. It is likely that spawning is occurring along the rocky, wind-swept shores of the islands: much of the rocky shoreline of the lake itself is covered in silt, and eggs laid in those locations would be smothered.

The 1999 survey indicates that a moderate pike population occurs in Wakaw Lake, with numbers increasing in abundance since 1978. The variety in size and age classes suggests that the population is healthy and stable. Capture of young-of-the-year pike in September by gillnet and electro-fishing verifies that reproduction of this species is successful: the shallow, weedy bays (particularly) in the west arms, provide suitable spawning habitat for this species.

Although the perch population is extremely abundant in Wakaw Lake, the majority of fish captured were small in size, averaging 50 g in weight. This species is important as a food supply for pike and walleye. Perch is a popular sport fish for children, who have great success fishing for them off docks. The large number of perch caught in the seine nets indicates that this species is successfully reproducing in the lake.

Wakaw Lake is a popular lake for water-based recreation, including water skiing, swimming and fishing. Seadoos are also popular, and have been a concern to residents of several subdivisions who feel use of this type of water craft should be restricted: Wakaw Lake is a very narrow lake with limited areas in which to operate power boats. The new boating regulations, which limit operation of personal water craft to people over 16 years of age, should help alleviate congestion.

An estimated 25 350 angler-hours were spent fishing on Wakaw Lake between May 8 and September 5, 1999. This is lower than the 40 000 angler-hours estimated in 1980 (Merkowsky & Durbin 1984). Anglers took home mainly pike (48%), followed by perch (39%), and walleye (13%). No attempt was made to estimate the harvest of fish taken during the winter months. In comparison to other water bodies located in south-central Saskatchewan, fishing pressure, in terms of angler-hours per hectare, is high on Wakaw Lake:

Fishery	No. of angler-days	No. of angler-hr	No. of angler-hr/ha	Harvest, kg	Harvest, kg/ha	Source	
Delaronde	8 640	45 200	3.4	30 990	2.3	Tinline & Chen	1981
Turtle	12 508	46 112	7.2	17 170	2.7	Tinline & Durbin	1982
Wakaw (1980)	12 142	40 067	38.7	16 333	15.8	Merkowsky & Durbin	1984
Murray	9 090	24 300	17.4	15 730	11.2	Durbin	1980
Jackfish	17 980	29 120	3.6	14 260	1.8	Durbin	1980
Wakaw (1999)	10 560	25 350	21.7	3290	2.9	Present study	

Despite the heavy fishing pressure, the harvest from the sport fishery, estimated at 2.9 kg/ha, is low compared to other fisheries and to past harvest data collected from Wakaw Lake. (It must be mentioned that the 1980 Wakaw Lake survey used data extrapolated from Turtle Lake, so results must be interpreted with caution.) Most anglers contacted during the survey did not have fish in their creels, and many complained about their lack of fishing success. Wakaw Lake is a very productive lake, and it is likely that the gamefish are feeding on natural food resources rather than taking a hook.

5. RECOMMENDATIONS

- Gamefish populations are being well-maintained by natural reproduction. The age composition of gamefish taken in the survey nets reveals a good variation in classes, suggesting stable, healthy populations. No stocking is recommended.
- As no commercial or domestic fisheries operate on Wakaw Lake, the fish are exploited only by anglers. Although the fishing pressure on the lake is high in terms of angler-hours/ha, harvest of gamefish is relatively low. Therefore, no reduction in limits is necessary at this time. However, the fishery should continue to be monitored through sport fish surveys and periodic creel surveys to ensure that no negative changes occur in the fish populations.
- Future plans for subdivision expansions or other developments should be carefully reviewed to ensure that impacts to the aquatic ecosystem are prevented. The establishment of 30 m or wider undisturbed buffer strips between any disturbed areas and the lake is recommended for any new developments, including subdivisions, roadways or other structures.
- Local residents and cottage owners around the lake have expressed concerns about deteriorating water quality and increased sedimentation into the lake. It is recommended that further studies be carried out to assess the influences of land use practices, developments and other factors on the lake, and to establish a long-term management plan for the watershed. Development of a local Stewardship Committee would assist in education of the resource users around the lake.

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Appendix 1

Limited Report:

Wakaw Lake water quality monitoring (1999) and future trophic impact assessment.

Prepared for Saskatchewan Environment and Resource Management, Environmental Protection Section, Parkland Ecoregion, Saskatoon.

By

Ken Scott, PhD.

April 2000.

SECTION 1

Background and summary of monitoring data collected in September 1999, in response to fish-kill incidents on Wakaw Lake

Introduction

Wakaw lake is a high use recreational water body located approximately 90 km north east of Saskatoon, adjacent to the Wakaw town site. Public usage includes sport fishery, general boating and swimming activities *etc.*, and extensive lakefront cottage developments.

Hedlin. Menzies & Associates carried out a land and water use study at Wakaw Lake in the mid 1970's (Saskatchewan. Land Protection Branch, 1975). They report made a number of recommendations concerning activities and development issues impinging on lake water quality, including aspects of "lakeshore carrying capacity".

Wakaw lake was subject to a one year study by SERM during1979-80 in response to concerns about degrading water quality and increased nutrient loading (SWPC, 1985). That study concluded that the lake water quality met provincial criteria for contact recreation and the protection of aquatic life.

An inspection of septic tank operations around the lake has been carried out (Lloyd Wedewer, pers. comm.). However, sub-division development (stormwater runoff), agriculture, and other activities (including septic leachate) are sources of nutrient loading to the lake.

An overall decline in the lake's walleye *(Stizostedion vitreum)* population indicates the lake ecosystem may be changing in some way (J. Merkowsky, pers. comm.). SERM fisheries staff responded to summer fish-kill incidents by test netting juvenile fish abundance and composition in September 1999. In addition, water samples were collected for chemical analysis, and measurements of dissolved oxygen/temperature profiles were made. This document summarizes these water quality results. It must be stressed that interpreting a one-off sampling is very limiting when one considers the extent of seasonal fluctuations.

Materials and Methods

Three sites were selected which corresponded to east, central, and west areas of the lake. Water samples were collected at 1.0 m depth from each site, including a sample at 10.0 m at the central deep site using a kemmerer bottle. Dissolved oxygen and temperature were measured with a YSI model 57 meter.

Conductivity and pH were also measures in the field. Samples for zooplankton and phytoplankton were also collected and preserved in 15% Formalin solution and lugols iodine respectively.

Results

Dissolved oxygen and temperature profile

There was no significant temperature stratification present. Oxygen was similar to 7.0m at 6.6 mg/L (~ 70% saturation). Oxygen dropped off between 9 and 10 m to 3.5 mg/L, reflecting additional benthic oxygen consumption processes. Notable is the depressed oxygen saturation throughout the water column. Since phytoplankton biomass was moderate (see below), there are indications that oxidation of dissolved organic carbon, ammonia, and possibly sulfide were responsible.

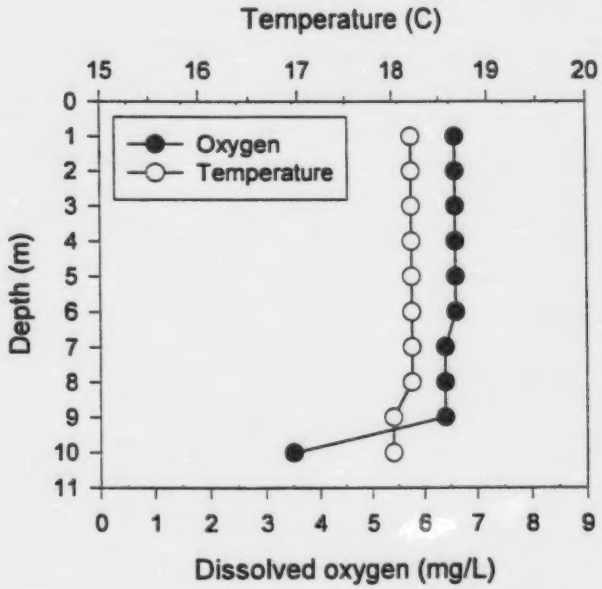

Figure 1. Dissolved oxygen and temperature profile at Wakaw lake, station 2 (deep site), September 1st 1999.

Chemical analysis and water clarity

Some of the measured parameters varied substantially between the three sites. Selected results are summarized in Figure 2. Chlorophyll a was highest at site #2 in both the top and bottom samples (18 - 16 µg/L, respectively). Site #1 had the lowest chlorophyll a (< 1 µg/L). Turbidity results reflected chlorophyll distribution,

suggesting that phytoplankton were the main light attenuating agent. Total-P was between 0.04 and 0.06 mg/L. These levels could theoretically permit a higher phytoplankton biomass than was measured, so zooplankton grazing is implicated.

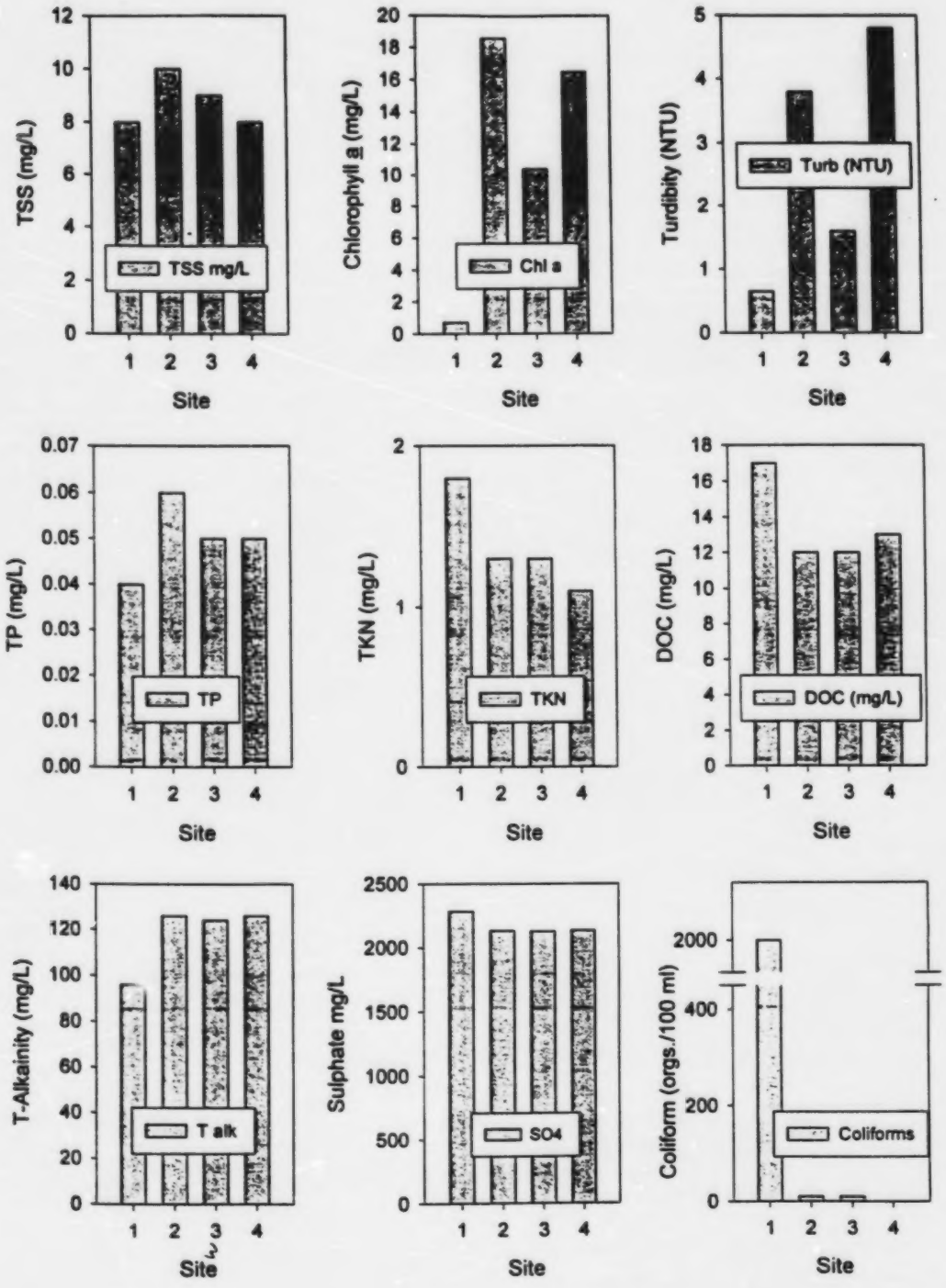

Figure 2. Selected chemical analyses from Wakaw Lake, September 01, 1999 (#4 = sample from 10 m at site # 2, all other samples takes at 1.0 m).

Total-N was elevated at site #1compared to other sites (1.8 *vs* 1.3 mg/L), as was dissolved organic carbon (17 *vs* 12 mg/L). Conversely, alkalinity was reduced at site #1. However, perhaps the most significant finding was the high number of total coliform bacteria at site #1 (2000/100 ml *vs* ≤ 10/100 ml at the other sites).

The elevated total-N, DOC, and coliforms together are suggestive of a local contamination source (wildfowl deposition is unlikely). However, other than the high coliform count, higher total-N and DOC may simply be the result of high macrophyte production and organic turnover at this (shallow) end of the lake. The site differences, and especially the coliform counts, merit further investigation.

Secchi disk depth varied between 1.8 and 1.2 at the shallow and deep sites respectively. These values represent eutrophic conditions.

Biological analysis

Microscope analyses of phytoplankton and zooplankton have not been completed at the time of this report.

Comparison of selected parameters with 1979-80 study

Tables 1 and 2 show a comparison of selected data from 1979 with the 1999 results. The data do not allow statistical comparison, but do give a qualitative indication of potential changes in the lake. The mean values from 1979-80 are generally derived from 15-16 stations, representing shallow and deep water sites. The 1999 data is from only 3 sites, but still representing shallow and deep water sites.

Conductivity (*i.e.* salinity) maximum was slightly higher in 1999 than any of the open water data from 1979-80. Apart from one pH value over 9.0 in 1979, pH was relatively similar in 1999. Total-P, TKN, and Chlorophyll *a* maxima and means were relatively unchanged. Secchi disk ranges were similar, except that the minimum value of 1.2 m measured at the deep water site in September 1999 (not shown in Table 1) was lower than the 1979-80 study. The 1999 coliform maximum was twice as high as the 1979-80 maximum.

Comparing the four dissolved oxygen profiles, the 1999 percent saturation was lower than any of the 1979-80 profiles above 7 m, by 16 to 30 %

	Conductivity (uS/cm)		pH		Total-P (mg/L)		TKN (mg/L)		Total coliforms #/100 ml		Chlorophyll a (mg/m3)		Secchi depth (m)	
	max	mean	max	mean	max	mean	max	mean	max	mean	max	mean	max	mean
August '79*	3390	3350	9.4	8.6	0.06	0.04	1.4	1.32	975	490	12	7.4	2.0	1.9
October '79	3000	2960	8.6	8.3	0.06	0.04	1.4	1.32	360	182	12	6.1	2.2	2.0
June '80*	3300	3200	8.6	8.4	0.06	0.05	1.5	1.35	5	3	18	12.6	1.9	1.6
Sept '99	3780	3627	8.2	8.1	0.06	0.05	1.8	1.35	2000	363	19	11.5	>1.8	1.6

Table 1. Comparison of selected data collected in 1979-80 and 1999 at Wakaw Lake.

Depth	Dissolved oxygen (% saturation) at deep water station			
	August '79	October ' 79	June '80	September '99
surface	100	93	84	70
1	100	92	84	70
2	100	92	85	70
3	93	91	86	70
4	85	92	85	70
5	82	92	85	70
6	76	92	84	70
7	61	92	85	68
8	58	92	84	68
9	45	91	81	68
10	33	89	81	39
11	13.6	89	-	-
12	11	-	-	-
maximum	100	93	86	70

Table 2. Comparison of dissolved oxygen data measured in 1979-80 and 1999 at Wakaw Lake (deep water site).

Comparison of selected parameters with provincial SWQOs

All parameters corresponding to specific SWQOs for protection of aquatic life and contact were met.

Discussion and conclusion

As a predominantly shallow, clear-water lake, Wakaw has most of its nutrients tied up seasonally in macrophytes. The lake supports abundant *Chara* growth (macroscopic algae which form dense rootless stands over the sediments), and other aquatic plants. High macrophyte production and a relatively high dissolved organic pool within the lake, may predispose oxygen depletion in shallow bays during calm warm weather, especially if cloudy conditions follow a period of high radiation input.

Macrophyte dominated lakes like Wakaw are "buffered" against *linear* trophic advancement to some extent. Rather, they may tend to maintain macrophyte domination up to a saturation point , after which a rapid switch to phytoplankton domination may take place. Once switched, restoration to the former state (by implementing a nutrient reduction program) is impeded due the extent of ecological alteration. Much of the "buffering" of trophic advancement in macrophyte dominated lakes is due to the stability of existing secondary and tertiary production, or top-down controls (Moss et al., 1996).

Summer fish kills in this lake may result from the following, alone or in combination; (a) oxygen depletion; (b) unionized ammonia, (c) hydrogen sulfide, (d) an organic component of the system or its breakdown/transformation products (for example *Chara* are renowned for imparting a musky odor to water, although no documentation of toxicity associated with these compounds was found in a literature search) (e) pathogenic organisms (f) cyanobacterial toxins (g) anthropogenic toxins.

Due to the restricted but variable location of the fish-kills, it seems unlikely that a point source of toxins is responsible (e.g. contaminated seepage or an agricultural drain). The depressed oxygen saturation throughout the water column, indicated susceptibility to development of critical oxygen levels. Although no sediment samples were taken, it was apparent in the test-netting areas that sediments of high organic content and anaerobic condition are present.

The decline of walleye populations in Wakaw lake may be a symptom of factors causing fishkill. Associated with this may be more subtle ecosystem changes. Factors which must be considered are spawning habitat, food quality for early life stages, predation interactions (especially the pike:perch:zooplankton dynamic), and over-wintering conditions. As a small lake, selective fishing pressure may be significant for walleye. There was an indication that salinity may have increased

over the previous twenty years (not conclusive). Since Wakaw lake is supported in large part by an evaporation-groundwater flux, deterioration of groundwater quality, and changes to water table heights are important issues. More information is being sought with respect to salinity and walleye.

Monitoring - water quality study
Recently a community monitoring initiative has been launched by a group of concerned citizens at Wakaw Lake. This group has joined the Friends of the Saskatchewan River Basin, partnered with the Saskatchewan Wetlands Corporation, SERM and other agencies. More information is being sought on the extent of these initiatives with regard to Wakaw Lake. This is likely to lead to a much improved local handle on issues affecting the lake. However, no monitoring has been under taken so far. It may be an appropriate time to springboard the community initiative with a detailed study of the lake and current land use practices. Twenty years have passed since the last assessment. Outlines of comprehensive study components are given in Section 2

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Jennifer Merkowsky, SERM fisheries, Saskatoon office.

Lloyd Wedewer, RM of Hoodoo, Cudworth Office. Tel. 306-256-3281

Conservation Officer, SERM, Humbolt office. Tel. 306-682-6726

WAKAW LAKE FISH HABITAT MAPPING, 1993
GIS Database Metadata

Contact Information

Contact person: Wen K. Liaw, Ecologist
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Contact address: 112 Research Drive, Saskatoon, SK, S7K2H6
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Field Work and Database Information

Date: conducted between July 7, 1993 and August 19, 1993
Methods: habitat features in the foreshore, backshore and littoral areas were marked on the field map which was traced from the township airphoto map, CSMA 78004-30-L28-84; approximate scale, 1:9,600.
GIS Datebase: Geographic Information System (GIS) databases and maps were generated by digitizing habitat features on the field map onto the map of Wakaw Lake extracted from the digital source map (see below).
GIS software: PC ARC/INFO 3.5.1 and ARCVIEW GIS version 3.0 (Environmental Systems Research Institute Inc.)

Source Map Information

Organization: SaskGeometics Division (formerly, CSMA), SPMC
Format: Topographic Base Map Data Set, DXF for MS-DOS
Map scale: 1:50,000
Map sheet number: 73A12
Data currency: 1973 (?)

Data Quality Information

Positional Accuracy
Horizontal positional accuracy: undetermined
Vertical positional accuracy: undetermined

GIS Map Projection Information

UTM Zone 13
Datum: NAD83 CNT
Spheroid: GRS 1980

GIS Map Title and Description

Map 1. Wakaw Lake and Its Immediate Drainage Area

All features on this map, except names of places and the Gazetteer position, were extracted from the source map.

Map 2A. Wakaw Lake Bathymetry

This bathymetric map shows the various depth zones and representative spot depths in Wakaw Lake. It was created by digitizing and fitting the old sounding map (Sport Fish Section, Fisheries Branch, August 20, 1979; source map unknown) onto the Wakaw Lake Map (Map 1). The 2-m zone is based on new sounding taken in 1993.

The following morphometric data of Wakaw Lake were derived from this bathymetric map:

Depth zone	Area (m^2)	Area (% total)	Volume (m^3)	Volume (% total)
0-2 m	6,708,862	57.6	16,129,449	39.8
2-5 m	1,325,789	11.4	12,798,569	31.6
5-10 m	2,814,736	24.1	10,223,759	25.3
10-13 m	805,761	6.9	1,327,260	3.3
Total	11,655,148	100.0	40,479,038	100.0

Mean depth = 3.47 m; Maximum depth = 13.1 m

Length of lake shore = 45,655 m; Length of island shore = 3,428 m; Total shore length = 49,083 m

Shoreline development = 4.06 (islands included), or = 3.77 (islands excluded)

Area of islands = 107,035 m^2

Note, the newly calculated water area (1,166 ha) is slightly more than the number (1,020 ha) that is usually quoted in the Sport Fish Management Study Report.

Map 2B. Wakaw Lake Bathymetry

Same as Map 2A except that depth contour lines instead of zones are shown.

Map 3. Wakaw Lake Backshore Development

Wakaw Lake is surrounded by agricultural land. However, four major categories of land uses can be recognized in the shore-land area: agricultural, cottage subdivision, natural

and recreational. Agricultural use includes pasture and crop land; and group camps, campgrounds and regional park are included in the recreational land use category. The wooded areas are considered in natural or near-natural status. The length of shoreline (islands included) by land-use category is estimated as follows:

Land use	Shore length (m)	% of total
Agricultural	6,563	13.4
Cottage subdivision	19,068	38.8
Natural	21,355	43.5
Recreational		
Group camp	1,029	2.1
Regional Park	1,068	2.2
Total	49,083	100.0

Approximate locations of boat launches (6) and public beaches (5 with a total length of about 844 m) are also shown on the map.

Map 4. Wakaw Lake Backshore Slope

The slope in the immediate area above the high water mark was visually assessed according the following criteria: gentle - low, flat, <10 degrees; moderate - about 10 -45 degrees; and steep - > 45 degrees.

The length of shoreline by backshore slope and land use is shown in the following table (number in brackets represents percent in total):

Land use	Slope			Total
	Gentle	Moderate	Steep	
Agricultural	6,206 (94.6)	357 (5.4)	0	6,563 (100.0)
Cottage	8,998 (47.2)	4,791(25.1)	5,279 (27.7)	19,068 (100.0)
Natural	10,030 (47.0)	6,282 (29.4)	5,043 (23.6)	21,355 (100.0)
Recreational:				
Group camp	526 (51.1)	0	503 (48.9)	1,029 (100.0)
Regional park	443 (41.4)	626 (58.6)	0	1,069 (100.0)
Sum	26,203 (53.4)	12,056 (24.6)	10,824 (22.0)	49,083 (100.0)

Contour lines at 25' (7.6 m) intervals are also provided to show the topography in the immediate drainage area of the lake; the first contour line next to the shoreline indicates an elevation of 1675' (510 m).

Map 5. Wakaw Lake Backshore Vegetation

A strip of vegetation generally exists between the lake and the surrounding cultivated farmlands and pastures. Five major types of vegetation cover were identified: grass, marsh, shrub, shrub/grass, and tree. Grass consists of native prairie and landscaped grasses; the latter were found mostly in cottage subdivisions and recreational areas, whereas the former were prevalent on pastures and along the edges of farmlands.

Table below contains the length of shoreline by dominant backshore vegetation and land use (number in brackets represents percent in total):

Vegetation	Land use					Sum
	Agricultural	Cottage	Natural	Recreational		
				Group camp	Regional Park	
Grass	4,548 (69.3)	1,794 (9.4)	1,549 (7.3)	359 (34.9)	0	8,250 (16.8)
Marsh	0	1,695 (8.9)	47 (0.2)	0	0	1,742 (3.5)
Shrub	1,190 (18.1)	3,681 (19.3)	8,473 (39.7)	167 (16.2)	1,069 (100.0)	14,580 (29.7)
Shrub/grass	354 (5.4)	1,864 (9.8)	363 (1.7)	0	0	2,581 (5.3)
Tree	471 (7.2)	10,034 (52.6)	10,923 (51.1)	503 (48.9)	0	21,930 (44.7)
Total	6,563 (100.0)	19,068 (100.0)	21,355 (100.0)	1,029 (100.0)	1,069 (100.0)	49,083 (100.0)

Woodlands in the immediate drainage basin are also depicted on the map. However, the information is not current and some of the wooded areas may have been cleared for agricultural purposes over the years.

Map 6. Wakaw Lake Foreshore Substrate

The natural substrate of Wakaw Lake's foreshore consists mainly of rock (of various sizes) in clay. However, due to heavy development of cottages and resorts, many areas have been altered. Shoreline alterations included building cement or railroad tie retaining walls and putting sand, gravel and rocks in front of cottages or developed areas.

The length of foreshore by substrate type is summarized in the table below:

Substrate	Shore length (m)	% of total
Cement or railroad tie retaining wall	262	0.5
Clay	4,902	10.0
Gravel (gravel and gravel/sand)	177	0.4
Rock (rock/clay, rock and rock/sand)	33,700	68.6
Sand	776	1.6
Sand/rock (sand/gravel and sand/rock)	2,796	5.7
Sandy silt	6,470	13.2
Total	49,083	100.0

Map 7. Wakaw Lake Vegetation and important Fish Habitat

Emergent vegetation in Wakaw Lake consisted mainly of bulrush and cattail. Extensive emergent vegetated areas were found in both ends of the lake, near the entrance of Salinity Creek at Poplar Point and around the islands. The littoral area (< 2 m deep) was almost entirely covered with submerged Chara.

The entire littoral area with its diverse habitats (consisting of various types of aquatic vegetation and bottom substrates) is considered an important spawning and nursing ground for northern pike and yellow perch, as well as other fish species in the lake.

According to test-netting results, Wakaw Lake has a moderate, naturally reproducing walleye population. Since none of the tributary creeks appears to be suitable for spawning because of limited flows and unsuitable substrates, walleye in Wakaw Lake must have adapted to spawn successfully in the littoral zone and along the foreshore areas. Potential walleye spawning areas included the rocky shoals identified near the islands (Map 7) and windswept gravel and sand/rock foreshore areas (see Map 6).

The following table presents approximate estimation of the vegetated areas and the rocky shoals near the islands (more accurate data could have been obtained, if a Global Position System (GPS) were used to map the areas):

Habitat	Area (ha)
Chara	629
Cattail	9
Bulrush	3
Bulrush & Cattail	29
Rocky shoal	9

Appendix 3

WAKAW CREEL SURVEY 1999

Date: _____ **Time:**_____ **Weather:** _____

Total Number in Party: _____ **Age and Sex:**

	Child	Adult	Senior
Male			
Female			

Fishing from: BOAT____ SHORE_____

Place of Residence: _____

Reason for Visit:

Cabin Owner _____ Camper _____ Day Visit _____

Interviewed on another date? _____ **Any fish caught?** YES NO

Today's Catch:

Species	Number Kept	Number released	Fork length measurements, cm
Walleye			
Pike			
Perch			

Time fished today:

_____ **hours X** _____ **# in party =** _____ **Angler/hrs**

How much longer do you intend to fish today? _____ **hrs**

_____

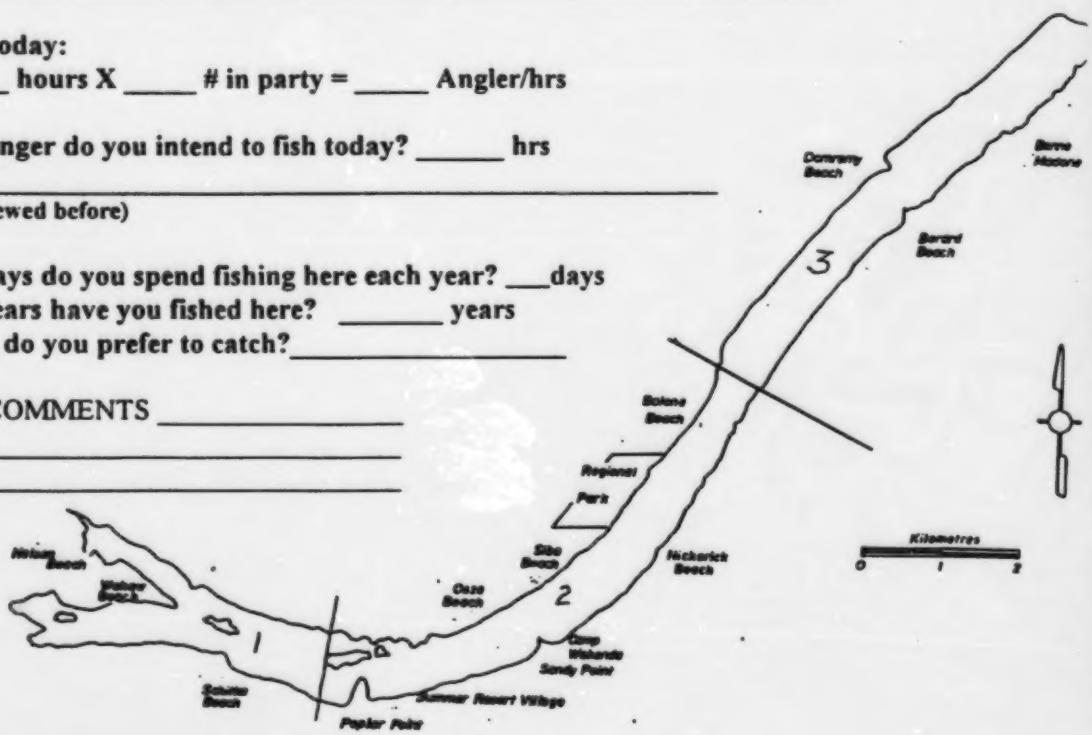
(Omit if interviewed before)

How many days do you spend fishing here each year? ___**days**
How many years have you fished here? _____ **years**
What species do you prefer to catch?_____

ANGLER'S COMMENTS _____

_____

_____



Interviewer _____ **Area Fished** _____

Appendix 4. Creel census survey dates, and times of interview shift, 1999.

Date	Shift	Weather/comments	Number of Parties Contacted
Mon, May 11	8 a.m.-12p.m.	Snow, wind	0
Fri, May 21	4p.m.-8p.m.	Cold, rain	3
Sat, May 22	12p.m.-4p.m.	Cloudy, calm, 12C-Victoria Day Weekend	17
Sun, May 30	4p.m.-8p.m.	Warm, clear, light winds	11
Sat, June 5	4 p.m.-8p.m.	Sunny, warm	11
Thu, June 17	4 p.m.-8p.m.	Sunny, breezy	5
Tues, June 22	8 a.m.-12p.m.	Cloudy, rainy, 18C	8
Sat, June 26	12 p.m.-4p.m.	Heavy rain	0
Fri, July 2	4 p.m.-8 p.m.	Windy, overcast, cool	29
Sun, July 11	12 p.m.-4p.m.	Clear, windy, 20C	15
Wed, July 21	4 p.m.-8p.m.	Hot, sunny, slight breeze	35
Sun, July 25	4 p.m.-8p.m.	Cold, windy, rain	6
Fri, Aug 6	12 p.m.-4 p.m	Calm, light cloud, 22C	20
Sun, Aug 8	4 p.m.-8p.m.	Cloudy, 22C	17
Mon, Aug 29	12 p.m.-4p.m.	Warm, windy 23C	11
Wed, Sept 1	4 p.m.-8 p.m.	Windy, cool	32
Sun, Sept 5	8 a.m.-12 p.m	Warm, sunny	13

Appendix 5. Water quality parameters measured at Wakaw Lake in 1999.

Date	Depth,m	Temp,° C	Oxygen, mg/L	pH	Conductivity, uS/cm	GPS location	Secchi depth,m
May11	1.0	7.8		8.6			
May 21	1.0	10.8	11.9	8.3			
	2.0	10.9	11.2				
	3.0	10.9	11.6				
	4.0	10.9	11.4				
	5.0	10.9	10.9				
June 14	1	16.8	9.9	8.70	3610	52 40 48.4 105 34 54.6	2.0
	2	16.5	9.8				
	3	16.0	9.8				
	4	16.0	9.7				
	5	16.0	9.7				
	6	15.9	9.5				
	7	15.9	9.4				
	8	17.7	8.8				
	9	15.3	8.1				
	10	15.2	7.7				
	11	14.8	7.0				
	12	14.3	3.8				

Date	Depth,m	Temp,° C	Oxygen, mg/L	pH	Conductivity, uS/cm	GPS location	Secchi depth,m
July 19	1.0	20.0	9.7	8.41	2740	52 40 14.6 105 33 06.8	2.0
	2.0	19.0	10.0				
	3.0	18.6	9.6				
	4.0	18.3	8.7				
	5.0	18.4	8.3				
	6.0	18.0	8.0				
	7.0	18.0	7.7				
	8.0	17.9	7.3				
	9.0	16.8	6.9				
Sept 1	1.0	18.2	6.6	8.26	3540		
	2.0	18.2	6.6				
	3.0	18.2	6.6				
	4.0	18.2	6.6				
	5.0	18.2	6.6				
	6.0	18.2	6.6				
	7.0	18.2	6.4				
	8.0	18.2	6.4				
	9.0	18.0	6.4				
	10.0	18.0	3.5				
Sept 21	1.0	13.2	9.2	8.44	3660	52 39 23.5 105 36 30.0	2.5
	2.0	13.2	9.1				
	3.0	13.2	9.0				
	4.0	13.1	8.8				
	5.0	13.1	8.7				
	6.0	13.1	8.7				
	7.0	13.0	7.8				

Appendix 6. Numbers and species of fish collected by seine hauls in Wakaw Lake, 1999.

Date	Haul #	Location	Length of shoreline sampled,m	Substrate Type	Perch	Spottail Shiners	Darters	Pike	Walleye	Stickle back
June 14	1	Oleksyn Beach	5	rock/*Chara*	18	34	6	-	-	-
	2	Oleksyn	6	rock/*Chara*	-	21	2	-	-	-
	3	Oleksyn	10	sand	20	49	24	1	-	-
	4	Regional Park	20	sand/ooze	-	1	1	-	-	-
	5	Regional Park	10	sand/ooze	167	101	11	-	-	-
	6	Osze West	10	rock/emergents	17	1	3	-	-	1
	7	Osze West	10	rock/emergents	39	16	3	-	-	-
July 19	1	Nickorick Beach	Used boat	rock, *Ruppia, Chara*	34	20	-	-	2	-
	2	Nickorick Beach	Used boat	vegetated ooze, rock	300	200	1	-	3	1
	3	off Walleye Island	Used boat	rock	300	100	6	-	-	-
Aug 6	1	Herman's place	used boat	rushes	25	100	-	-	-	-
Sept 1	1	across from Domremy Beach	15		100	25	-	-	-	-
	2	Nickorick	10	gravel/ooze	50	200	1	-	-	-
	3	Nickorick	20	gravel/ooze	150	300	1	-	-	-
	4	Sandy Point-at Camp Wakonda	25	sand	25	30	10	-	-	-

Appendix 7. Numbers and species of fish collected by minnow trap in Wakaw Lake, 1999.

Date	Sample #	Location	Perch	Spottail shiners	Darters	Stickleback
June 14	1	west of Domremy Beach	3		2	1
June 15	2	Off Herman's dock			4	3
June 16	3	West of Herman's	1			
July 19	4	Between Balone & Domremy Beach	2	1		
July 20	5	Off Walleye Is				

Appendix 8. Numbers and species of fish captured by standard gang gillnets in Wakaw Lake, 1999.

Net Set #	Set Date	Length, m	Depth of set, m	Location	Location Description	Walleye	Pike	Perch	White sucker	Total
1	June 14	60	1.1 - 10.1	52 41 25.0 105 33 57.3	Balone Beach	7	10	4	52	73
2	June 14	120	1.4 - 8.4	52 40 40.5 105 35 25.7	Between Domremy Beach & Regional Pk	31	22	12	67	132
3	June 15	60	2.4 - 7.4	52 39 28.7 105 36 30.8	Regional Park pumpsite	11	6	7	14	38
4	June 15	120	2.4 - 9.4	52 38 52.4 105 37 33.6	Sandy Point	33	11	2	49	95
5	June 16	120	2.0 - 7.4	52 38 34.6 105 38 50.9	Osze West Beach	33	27	4	34	98
6	June 16	60	1.2 - 1.3	52 38 42.4 105 39 56.9	Off island west of Osze	5	15	7	6	33
7	July 19	120	2.2 - 6.5	52 42 14.6 105 33 06.8	East side of Domremy Beach	49	7	17	27	100
8	July 19	60	3.0 - 11.8	52 41 16.4 105 34 41.4	Between Balone & Domremy Beaches	3	1	17	12	33
9	July 20	120	2.2 - 8.8	52 38 55.7 105 36 58.6	East of Sandy Point	35	6	2	30	73
10	July 20	60	1.3 - 1.3	52 38 45.8 105 39 50.4	Off west end of second island, toward N shore	2	10	6	1	19
11	Sept 21	120	2.0 - 6.0	52 38 51.5 105 37 06.9	Bay just east of Sandy Point (same as set 9)	87	10	2	27	126
12	Sept 21	60	1.5 - 1.5	52 38 51.1 105 37 06.9	Off west end of second island (same as set 10)	0	3	15	1	19
Total		1080				296	128	95	320	839
No. /100 m of net						27.4	11.9	8.8	29.6	77.7

Appendix 9. Numbers and species of fish captured by electro-fishing on Wakaw Lake on September 22-23, 1999. Each run lasted for 30 minutes in duration. Approximate size of fish is given below the numbers captured.

Run #	Location	Substrate	Walleye	Pike	Perch	White Sucker	Shiners
1	East from Sandy Point to subdivision opposite east side of Regional Park		1 2 lb	11 up to 2 lb	2 3 in	7	4
2	South shore opposite Regional Park, going east	*Chara*	2 2 lb	9 1-3 lb	19 small	0	hundreds
3	South shore, heading to Berard Beach	*Chara*, some emergent vegetation	0	18 1-4 lb	18	0	hundreds
4	Domremy Beach, heading west	emergent vegetation	0	17	13	0	24
5	From Regional Park west to Osze Beach	silt, sand and *Chara*	0	26 (18 y-0-y)	20	0	1
6	Poplar Beach east, along south shore	silt, sand, *Chara* and rock	1	8	21	0	hundreds
7	From Walleye Is westward around islands	*Chara*, rocks	0	5 (4 y-of-y)	29	0	2
8	NW bay of lake	*Chara*, sand, silt	0	16 y-o-y	108	0	few
9	Schneberger Beach area	*Chara*, sand, silt	0	7 (5 y-o-y)	60	0	1
Totals			4	74 adult 43 y-o-y	291	~~8~~ 7	thousands

Appendix 10. Determination of fishing effort in angler-hours on Wakaw Lake, 1999, using the total boat counts per day as a measure of angler-days.

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1. Boat and shore counts (average number of parties/shift) = morning + afternoon + evening

   Weekdays: (4 + 19 + 11.3) = 34.3
   Weekends+: (13 + 11 + 15.7) = 39.7

2. Angler-days = No. of parties x average no. of anglers/party x no. of days

   Weekdays: 34.3 x 2.4 x 82 = 6750
   Weekends: 39.7 x 2.4 x 40 = 3810

   Total angler-days = 10 560

3. Angler-hours = angler-days x avg no. hrs fished/trip*

   Angler-hours = 10 560 x 2.4
   = 25 350

\+ Weekends include statutory holidays.

* Trip is defined as the total effort expended in one day.

Appendix 11. Calculation of harvest of gamefish taken by anglers using the Wakaw Lake Regional Park filleting shed*.

	Weight of pike, kg	% of pike	Weight of walleye, kg	% of walleye	Total Weight, kg
May	13.5	100	0	0	13.5
June	146.8	54.4	123.3	45.6	270.1
July	326.5	77.9	92.5	22.1	419
August	329.5	87.3	48	12.7	377.5
Total	816.3	75.6	263.8	24.4	1080.1

* The gut cans were approximately 85 litre capacity (equivalent to 90 kg round weight of fish).

Appendix 12 . Estimation of the potential production of gamefish of Wakaw Lake, based on Ryder's morpho-edaphic index.

A. Calculation of potential fish production:

$y = 2\sqrt{x}$ (Ryder 1965)

where y = potential fish production (lb/ac/yr)
X = morpho-edaphic index
= total dissolved solids (TDS) / mean depth (d)

TDS = 3215 mg/L (sampled July 21, 1980)
d = 15.4 ft (From Mendis 1956)

$y = 2\sqrt{3215/15.4}$
= 28.9 lb/ac/yr
= 32.4 kg/ha/yr

B. Calculation of potential production of gamefish:

Based on the 1999 gill-netting survey, relative abundance (by weight) of the important species of fish is given:

Pike	19%
Walleye	42%
Perch	1%
White sucker	38%

Gamefish comprise 62% of the catch. Therefore, gamefish potential production is estimated as 62% of 32.4 kg/ha/yr

= 20.1 kg/ha/yr